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Mark B. McClellan — June 2001

PI - Signature — Date

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A. Introduction

The goal of this project was to (1) assess the validity of medical claims information for tracking breast cancer diagnoses, treatments, and outcomes; (2) use Medicare data, linked SEER cancer registry data, and claims data from large firms to analyze trends in diagnosis rates and staging, treatment, expenditures, and outcomes for Americans with breast cancer; and (3) analyze the cost effectiveness of alternative patterns of breast cancer diagnosis and treatment.

The first part of Section B reviews the work done on creating cohorts of breast cancer patients and assessing the validity of the selection procedure. The second part discusses our findings on trends in breast cancer costs, treatments, and outcomes with a particular emphasis on changes in the productivity of breast cancer care. The third part reviews our work on measuring the cost effectiveness of alternative patterns of diagnosis and treatment, and introduces some innovative statistical methods we developed to help address the problem of bias. The conclusion section reviews the main findings and describes the areas for future research identified by this project..

B. Body

B.1. The validity of medical claims information

Much of our initial work involved cleaning and processing the claims data and linked SEER-Medicare data that were intended to be the core of our research program. While the data checking and revision (working collaboratively with NCI and IMS) was time-consuming and did not lead to any publications, it did lead to some important improvements in the quality of the linked data, and will have an important impact on future linkages. For example, we were able to identify incomplete reporting of some claims files for some registry patients in certain registries and years, and we identified a general problem with identifiers for outpatient hospitals. We developed methods for conducting our analyses of outpatient providers using unlinked claim files that overcame this limitation, and we described how to avoid the problem in future SEER-Medicare linkages. As a result, all of the research groups using the SEER-Medicare data benefitted from our data work. In addition, we developed complete claims files for the entire Medicare population for patients who were ever treated on an inpatient or outpatient basis in association with a diagnosis of breast cancer. These very large files required considerable effort for data management and cleaning as well.

Despite the time required to develop reliable, complete analytic claims files from the SEER-Medicare data and our complete cancer Medicare claims data, we completed substantial work toward our specific aims. During the first few years of work, we completed the work of Aim 1 of our proposal: evaluating the validity of Medicare claims data for identifying cancer patients and studying cancer trends. We completed a manuscript that developed a comprehensive sensitivity-specificity (ROC) framework for evaluating different rules for identifying cancer cases from claims, and that also evaluated many other claims data issues such as the value of prior-years' data to exclude prevalent cases and the value of complete physician records (often unavailable in managed-care plans) to find cases (McClellan et. al. 1997a). The manuscript summarized our

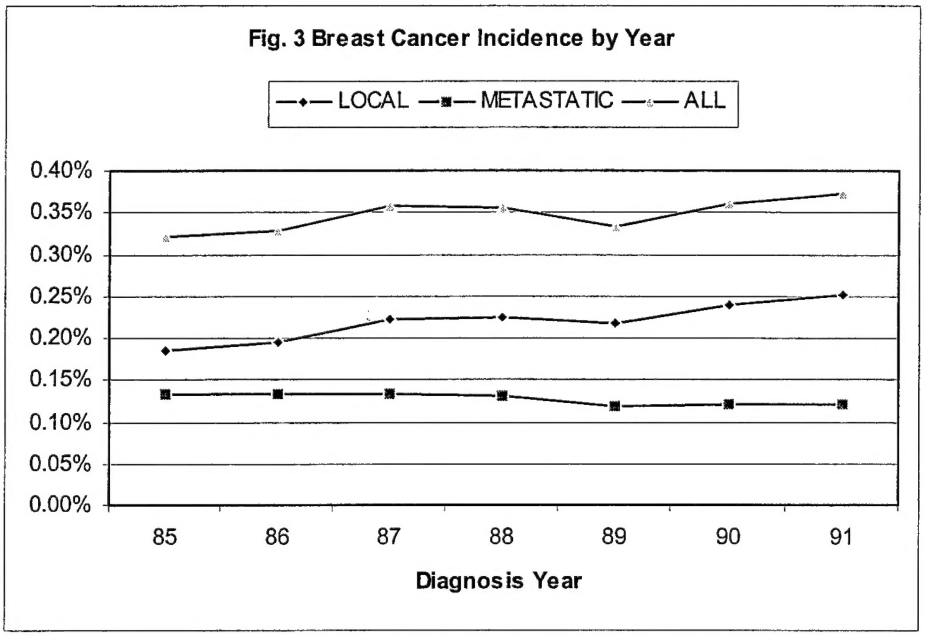
work on applying these methods to breast cancer. Figure 1, taken from the manuscript, illustrates the sensitivity and specificity of a range of sequential rules for identifying incident breast cancer cases from claims data. Our main conclusion, consistent with prior studies, was that claims data have important limitations in case-finding. On the other hand, our methods resulted in much higher sensitivity and specificity estimates than had been reported previously. Our "preferred" rules for identifying cancer cases yielded sensitivity and predictive-value positive estimates in the range of 75 to 80 percent or higher. Moreover, for true incident cases, claims data were surprisingly accurate in capturing the precise time of diagnosis (figure 2). Our next step was to evaluate the quantitative differences between analyses of cancer trends and/or the effects of alternative cancer practices based on claims data, versus analyses based on administrative data linked to registry (SEER) records.

B.2. Breast Cancer Trends

We used these two cohorts (SEER- and Medicare claims-based) to investigate Aim 2 in our proposal: studies of trends in breast cancer care. We conducted studies of trends in cancer incidence, treatment, and outcomes for breast cancer (McClellan 1997b). We also described trends in expenditures and utilization for breast cancer, with some notable preliminary findings. In contrast to the costs of care for many other serious chronic illnesses, expenditures per patient with localized (stage I or II) cancers have not increased noticeably for breast cancer patients. The flat expenditure trends in turn reflect two countervailing trends in utilization: declining rates of inpatient hospital care, offset by increasing intensity of treatment and expenditures in the outpatient setting. For patients with metastatic cancers, our results suggest that inpatient intensity of care and total expenditures are increasing steadily. Relatively flat trends in breast cancer outcomes, together with rising expenditures and intensity of care, suggest that productivity in breast cancer care (defined as the quantity of output for a given quantity of input) was potentially declining. We turned to examine this question in detail.

Building on the work on trends, we examined productivity changes in the treatment of breast cancer. These studies attempted to avoid the quality versus price bias common in such studies (the share of cost growth that produces better outcomes versus inflation) by assessing the outcome and cost effects of medical care at the level of a specific disease, namely breast cancer. Evidence for heart disease, depression, childbirth, other diseases suggested that the value of health improvements over time had far exceeded increases in treatment costs. However, there had been no previous studies of cancer care. It is important to understand productivity in cancer for several reasons. First, cancer will soon be the leading cause of death in the United States and will account for over 10% of all medical expenditures (second behind heart disease). Second, despite evidence of improved productivity for other conditions, death rates from cancer have been nearly flat for decades, leading to criticisms of the value of medical research and practice innovations in cancer care.

Estimating productivity in health care requires analyzing jointly changes in incidence, outcomes, and costs of care to reach empirical conclusions about productivity change. In the case of breast cancer, the results indicated the importance of including changes in incidence, rather than merely examining productivity conditional on diagnosis. Increased survival per case has been largely offset by rising



incidence, resulting in a constant, rather than declining, price index. We analyzed the costs and benefits of treatment changes for breast cancer over the period from 1985 to 1996 (Cutler and McClellan, 2001). Over time, several new innovations in therapeutic treatment of breast cancer have been made. These technological changes have added about $20,000 to per case costs over the 11 year period. In addition, detection technology advanced. Screening for breast cancer increased markedly over this time period and more sensitive screens allowed detection of smaller masses. As a result, overall cancer diagnosis and treatment rates rose. Between 1985 and 1991, for example, breast cancer incidence rates increased 10 percent (figure 3). This was offset partially in subsequent years by reduced rates of metastatic disease from cancers caught earlier, but incidence rates were still higher even a decade later.

To measure the benefits of these diagnostic and therapeutic changes, we calculated survival for women as a whole as a result of reduced breast cancer mortality. Looking only at mortality for women with breast cancer gives a biased estimate of the impact of technological change, as many of the new women treated will have much less severe cases of disease than women detected in previous years, and thus will naturally live longer. We expressed these population-based survival improvements on a per case basis to compare with per case treatment costs (or alternatively, the per case costs could be converted to a population basis). Survival after breast cancer increased by 4 months over this time period. The value of a year of life for a woman with breast cancer is the $100,000 health benefits less the $25,000 of basic medical and non-medical costs. Because the women we analyzed are elderly and most are out of the labor force, we assume no increased production. With a $75,000 net benefit of a year of life, the increase in survival is worth about $20,000. The value of increased survival is thus roughly equal to the cost increases for treating breast cancer. On net, technological change was neither beneficial nor harmful.

There are uncertainties in this calculation that could make technological change valuable or not. For example, we have not accounted for quality of life, which is believed by many to have improved over this time period. On the other hand, we have counted only treatment costs and have omitted the substantial increase in screening costs. These uncertainties are in addition to the usual uncertainty about the value of a year of life. On net, the costs and benefits are so close and the uncertainties

sufficiently high that we conclude that technological change was probably neutral, with no large change either way. Understanding why technological change in breast cancer was not as valuable as technological change for other conditions is difficult to answer and requires further study.

California Data Linkages. In collaboration with the Public Health Institute of California, we completed a linkage between the California Cancer Registry and California hospital discharge abstracts and death records in September, 1999. We are currently constructing cohorts of California cancer patients analogous to our national and SEER cohorts, and conducting analyses of trends in hospital utilization and treatment, inpatient expenditures, and serious complications requiring hospitalization in all California residents with breast cancer from 1991-96. In contrast to our Medicare studies, these analyses permit study of the differences in cancer incidence, treatment, resource use, and outcomes for patients with different kinds of health insurance (including managed care) (Table 1). Preliminary findings indicate that managed care enrolls with breast cancer tend to be younger and more affluent. There is not substantial difference in stage at diagnosis. Although older managed care enrolls are less likely to receive a mastectomy, overall treatment patterns do not differ significantly between FFS and managed care Medicare patients. However, outcomes are substantially worse for the managed care breast cancer populations, as measured by five-year mortality. We are currently applying instrumental-variables and MSX methods (see below) to studies of cancer treatment in California, determining whether differences in practice patterns have consequences for costs and health outcomes, and whether these effects differ across insurance type.

Table 1. Socio-Economic Status, Breast Cancer, and Managed Care

		Fee for Service	Managed Care	p-value	N	Variance
	Overall	0.930816	0.069184	0.0000	17692	0.064401
Age	65-74	0.928571	0.071429	0.0000	8484	0.066334
	75-84	0.927311	0.072689	0.0000	6686	0.067416
	85+	0.947661	0.052339	0.0000	2522	0.049620
Race	White	0.917039	0.082961	0.0000	12741	0.076084
	African-American	0.895652	0.104348	0.0000	575	0.093622
	Hispanic	0.951724	0.048276	0.0000	145	0.046264
	Other/None	0.976365	0.023635	0.0000	4231	0.023082
Median Income	<$15,000	0.932632	0.067368	0.0000	950	0.062896
	15,000-24,999	0.947965	0.052035	0.0000	2383	0.049348
	25,000-34,999	0.934312	0.065688	0.0000	5450	0.061384
	35,000-49,999	0.921708	0.078292	0.0000	6463	0.072173
	$50,000+	0.929681	0.070319	0.0000	2446	0.065401

		Mastectomy			Five Year Mortality		
		Fee for Service	Managed Care	p-value	Fee for Service	Managed Care	p-value
	Overall	0.564246	0.561275	0.8397	0.933225	0.968288	0.0001
Age	65-74	0.591394	0.612211	0.3149	0.928831	0.971292	0.0012
	75-84	0.579677	0.543210	0.0117	0.926893	0.954774	0.0776
	85+	0.434728	0.393939	0.3574	0.950883	1.000000	0.0673
Race	White	0.576600	0.552507	0.1292	0.935812	0.963942	0.0042

	African-American	0.557282	0.583333	0.7010	0.949791	1.000000	0.2033
	Hispanic	0.652174	0.714286	0.7381	0.875000	-	
	Other/None	0.527233	0.630000	0.0419	0.887640	1.000000	0.0712
Median	<$15000	0.538375	0.515625	0.7248	0.961165	0.958333	0.9452
Income							
	15,000-24,999	0.605578	0.596774	0.8453	0.933750	0.981818	0.0196
	25,000-34,999	0.581697	0.567039	0.5870	0.928372	0.969697	0.0114
	35,000-49,999	0.551788	0.571146	0.4005	0.937500	0.960784	0.1146
	$50,000+	0.526825	0.511628	0.7005	0.921488	0.982759	0.0027
			Stage at Diagnosis				
			Local			Metastatic	
		Fee for Service	Managed Care	p-value	Fee for Service	Managed Care	p-value
	Overall	0.766031	0.785948	0.1116	0.070318	0.072712	0.7522
Age	65-74	0.774816	0.795380	0.2418	0.075781	0.074257	0.8913
	75-84	0.782258	0.786008	0.8470	0.061613	0.072016	0.3914
	85+	0.694979	0.742424	0.2482	0.074895	0.068182	0.7751
Race	White	0.768487	0.789972	0.1118	0.072920	0.071902	0.9029
	African-American	0.706796	0.766667	0.3328	0.118447	0.100000	0.6741
	Hispanic	0.876812	0.857143	0.8787	0.029000	0.000000	0.6506
	Other/None	0.762769	0.750000	0.7669	0.058339	0.070000	0.6239
Median	<$15,000	0.729120	0.781250	0.3634	0.092551	0.046875	0.1111
Income							
	15,000-24,999	0.764940	0.822581	0.1389	0.069500	0.080645	0.6361
	25,000-34,999	0.769639	0.770950	0.9546	0.070896	0.086592	0.3060
	35,000-49,999	0.772369	0.798419	0.1784	0.066644	0.061265	0.6404
	$50,000+	0.756816	0.755814	0.9764	0.070800	0.081395	0.6034

B.3. Cost-Effectiveness

The original goal of Aim 3 of the project was to measure the cost-effectiveness of alternative patterns of breast cancer diagnosis and treatment using our instrumental-variables (IV) methods on breast cancer. The IV estimation method employs the use of a variable (the "instrument") that is correlated to the patients likelihood of receiving the treatment of interest, but uncorrelated to the patients likelihood of experiencing a particular outcome. The latter criterion is assumed to occur when the instrument is uncorrelated with observable characteristics of the patient that are known predictors of breast cancer outcomes, such as the patient's age, the stage at diagnosis, and the presence of co-morbidities. By measuring the difference in treatment rates and outcomes among patient groups that differ only in the value of the instrument, the resulting estimates of marginal treatment effects (difference in outcomes / difference in treatment rate) are considered *unbiased* (i.e., not driven primarily by unobserved or unaccounted for differences in patient characteristics). In general, the marginal treatment effect is considered an upper-bound estimate for the particular treatment used in the analysis, given that there might be other, less intensive, treatments that are correlated with the treatment of interest.

Our initial work with the Medicare claims-based breast cancer cohorts was focused on measuring the marginal effect on mortality of breast conserving surgery versus mastectomy. The goal was to identify an instrument possessing the properties described above. We investigated numerous potential variables based on a measure of "differential distance," defined as the distance (in miles) between the residence of patients to hospital providers with various structural characteristics (features that are fixed in the short-term) less the distance between patient's residence to providers without those characteristics. This class of IVs has the advantage of being available for a wide range of treatments and conditions, easy to construct once the basic technology is mastered, and of substantial policy interest in and of itself. In the specific application, we sought IVs associated with higher rates of use of mastectomy and breast-conserving surgery (BCS) for the treatment of breast cancer. Suitable variables included the presence of more than five (5) board certified oncologists on staff, the status of teaching hospital, defined as more than 10 full-time equivalent residents in training, and hospital providers with radiation treatment facilities ("specialized cancer centers").

TABLE 2: DESCRIPTIVE STATISTICS BY DIFFERENTIAL DISTANCE TO ONCOLOGY HOSPITAL
1986 -1993 STAGE 1,2 ELDERLY BREAST CANCER PATIENTS, SEER-LINKED MEDICARE CLAIMS DATA

		DIF DIST<=, > 8 MILES		INITIAL TREATMENT	
	Full Cohort (N=34,921)	NEAR (N=23,809)	FAR (N=11,112)	ONCOLOGY (N=16,828)	NON- ONCOLOGY (N=16,902)
DEMOGRAPHIC VARIABLES			Means and Rates		
Age	74.0	73.9	74.2	73.8	74.3
(SD)	(6.9)	(7.0)	(6.9)	(7.0)	(6.8)
Black	3.4	4.7	0.5	4.5	2.4
INITIAL TREATMENT AT ONCOLOGY H.	49.9	65.0	17.9	100.0	0.0
STAGE			Rates		
Stage 1, modified AJC	53.3	53.4	53.0	53.8	52.5
Stage 2, modified AJC	46.7	46.6	47.0	46.2	47.5
Local, historic	73.2	73.3	73.0	73.3	72.6
Regional-Distant, historic	26.8	26.7	27.0	26.7	27.4
TREATMENTS (5% sample)			5 Year Rates		
Mastectomy	77.4	75.2	81.9	74.9	81.1
Lumpectomy	64.5	66.7	60.2	67.0	63.1
Lumpectomry, no Mastectomy	19.6	21.8	15.4	22.0	16.8
Neither Lumpectomy or Mastectomry	3.0	3.1	2.8	3.1	2.1
Chemotherapy	10.6	10.6	10.7	11.2	10.3
Radiation	25.0	26.9	21.4	27.0	23.0
OUTCOMES			5 Year Rates		
Mortality	27.8	27.9	27.7	26.5	28.9
UTILIZATION			5 Year Days		
Acute hospital	19.2	19.7	18.2	19.6	19.3
	(26.5)	(24.6)	(27.4)	(26.5)	(26.7)
Nonacute hospital	6.4	6.9	5.2	6.3	6.5
	(28.8)	(27.2)	(29.5)	(28.7)	(29.1)
EXPENDITURES (1993 Dollars)			5 Year Expenditures		
Inpatient	14,712	15,554	12,970	15,132	14,566
	(18,684)	(16,149)	(19,738)	(18,874)	(18,556)
Outpatient	3,763	4,043	3,184	4,081	3,530
	(5,089)	(4,223)	(5,436)	(4,653)	(5,509)
Physician	11,569	12,490	9,877	12,404	10,912

	(8,247)	(6,982)	(8,729)	(7,977)	(8,502)
Hospice	136	149	108	155	121
	(1,395)	(1,314)	(1,432)	(1,315)	(1,494)
Home Health Agency	969	1,065	772	1,014	933
	(3,866)	(3,068)	(4,194)	(4,064)	(3,636)

In general, we found that differential distance to alternative types of cancer providers -- specifically, highly-specialized cancer treatment facilities and radiation treatment facilities -- is a strong predictor of initial as well as subsequent treatment by such providers, and (in race-specific analyses) is not associated with any significant differences in the observed characteristics or severity of disease of breast cancer patients. In turn, differential distance was also a strong predictor of less surgically-intensive management of breast cancer, particularly since 1989 (Table 2). In contrast to the characteristics of patients actually treated by specialized centers, the similarity of characteristics across these differential-distance groups suggested that we could attribute differences in outcomes across the instrumental-variables groups to the treatment differences. Our preliminary analyses suggested that the alternative treatment methods did not lead to substantial differences in mortality; however, less aggressive surgery lead to significantly higher medical expenditures. In part this was the result of expenditures for radiation therapy, but it also appeared to reflect more aggressive long-term follow-up as well. An important issue in these applications was the correlation between cancer diagnostic practices and cancer therapeutic practices. For example, Medicare beneficiaries living near cancer centers were somewhat more likely to undergo regular breast screening examinations, especially at advanced ages, and this resulted in a gradient of cancer incidence that declines with differential distance from a specialized cancer center. (See the work on measuring changes in the productivity of breast cancer treatment in Section B).

Further work with two-stage linear regression models confirmed that this correlation between diagnosis and treatment intensity required substantial modification of our instrumental-variables methods. Specifically, the resulting estimated treatment effects of mastectomy relative to breast-conserving surgery, accounting for variation in the instrument (in the first stage) and differences in patient characteristics (in the first and second stage), yielded marginal effects that were too large to be clinically plausible. In other words, treatment intensity is correlated with diagnostic practices, meaning that more intensive providers (e.g., more likely to perform mastectomy) are more likely to diagnosis early. Patients with early diagnosis experience better outcomes, so that the estimated treatment effect was measuring a combination of the effect of the treatment (and other, correlated, treatments) and the effect of early diagnosis. Attempts to account for earlier diagnosis by adjusting for stage or other measures of severity of illness and co-morbidities were unsuccessful, because cancer is a complex illness, stage is an uncertain measure of health status, and there are many unobserved patient characteristics that are related to both diagnosis, treatment, and outcome. Below we describe in more detail our attempts to account for this correlation, and present some new empirical methods we are testing that hold promise for dealing with some aspects of the problem.

We used our two samples of linked Medicare claims information to examine the validity of our instruments based on differential distance to cancer center hospitals. Detailed clinical information on patient health status is not readily available on medical claims data, and only limited information is available on SEER. To measure patient health status, in addition to demographics, we used the stage of cancer at diagnosis information available on the SEER-based cohort, and also developed a

co-morbidity index to apply to both the SEER and Medicare claims-based cohorts, using a modified version of the widely used Charlson co-morbidity index (Deyo et. al. 1992). Modification involved assigning specific weights for the breast cancer sample based on a logistic model of cancer-specific co-morbidities and long-term outcomes (e.g., four-year mortality). We used the index to compare values among breast cancer patients who live relatively near to or far from a cancer center hospital. Previous work has found a strong correlation between such observed co-morbidities and subsequent treatment choices for breast cancer (Newschaffer, et. al. 1996; Fleming et. al. 1999). A relationship between differential distance group and the index would suggest that the instrument would not yield un-biased treatment effects. In fact, we found that breast cancer patients that live relatively far from a breast cancer center hospital were diagnosed at a later stage, and had higher values on the index (more co-morbidities) than patients living relatively near. If this is true for characteristics that we observe, it is also likely true for patient characteristics that we cannot observe, making IV analysis of treatment effects more difficult. However, the relationship itself between distance and health status is an interesting policy question and research finding, given that access seems to play an important role in the diagnosis and treatment of breast cancer among the elderly.

In addition to accounting for difference in stage at diagnosis and health status, we also explored the possibility that our estimates of treatment effect would be more valid if we measured only cancer-specific causes of death. Because co-morbid conditions would confound our estimates of the effect of treatment on mortality, we hypothesized that a 'filtered' outcome measure might be less biased. Because not all deaths among those diagnosed with breast cancer have a cancer-specific cause, especially among the elderly, we wished to limit the analysis to deaths where the cause-of-death was specifically attributed to breast cancer. While it is also an interesting question to determine what other diseases contribute to mortality for breast cancer patients, our primary objective was to improve our estimates of the marginal effects of treatments on cancer-specific outcomes. Medicare enrollment data does not indicate the cause of death, only the date of death. Therefore, we employed two strategies to impute the cause of death. First, we adopted the "expenditure" method used in earlier work to assign a cause of death based on the condition causing the plurality of medical expenditures in the year prior to death (Garber, MaCurdy, McClellan, 1998). Because of concerns over the validity of these results, we started to attempt to validate the methods using multiple-cause-of-death data from the National Center for Health Statistics. That work was still ongoing at the end of the current project period (Kessler et. al, 2001).

Recently, however, we have developed additional empirical methods that account for random differences in patient characteristics among providers and the effect of multiple treatments and alternative treatment 'patterns' that providers adopt. These methods, known as multi-variate signal extraction (McClellan and Staiger, 1999), also improve the precision of the treatment effect estimate of the practice pattern by applying multi-variate signal extraction methods to filter out random noise (unobserved patient characteristics that effect the treatment received and outcome experienced). By determining which treatment patterns have the largest impact on patient outcomes, we can identify the providers that adopt the most effective practice styles, and the characteristics of those providers (for-profit, not-of-profit, urban/rural). As a result, we can examine the economic determinants of quality of care for cancer in addition to studying cost effectiveness. We are currently applying these methods to determine the most effective practice patterns for care of breast cancer. Similarly, we

are estimating the cost of each practice pattern, which will permit identification of the most cost-effective practice patterns.

Table 3. MSX Factors Results for Breast Cancer.

Minimum Provider Size=10

	Factor 1	Factor 2	Factor 3	Factor 4	MSE	R-Squared	
2 yr Mortality	-0.00192	-0.0019	-0.00349	-0.00356	0.01453	0.60034	
	(0.00003	0.00004	0.00002	0.00003	0.00041	0.02249	)
Mastectomy	-0.07262	-0.12329	-0.03205	-0.00547	0.00331	0.9995	
	(0.00014	0.00008	0.00014	0.00011	0.00087	0.00026	)
Lumpectomy	-0.15091	0.01926	-0.00799	0.00074	0.00396	0.99937	
	(0.00005	0.00028	0.00017	0.00012	0.00103	0.00033	)
Hyperthermia	-0.00039	0.0002	-0.00001	0.00488	0.00013	0.99935	
	(0	0	0.00001	0	0.00004	0.00037	)
Axilliary Node Excision	-0.02569	0.03302	0.00533	-0.00676	0.03624	0.59598	
	(0.00007	0.00004	0.00002	0.00003	0.00019	0.0042	)
NOS Radical Lymph Ex	-0.01426	0.03603	0.00227	0.01119	0.04933	0.43425	
	(0.00006	0.00002	0.00004	0.00003	0.00021	0.00473	)
Open Biopsy	-0.02826	-0.01985	-0.14175	-0.00077	0.00164	0.99987	
	(0.00011	0.00009	0.00004	0.00026	0.00056	0.00009	)
Closed Biopsy	-0.0988	0.02949	-0.0126	0.00897	0.08685	0.6739	
	(0.00014	0.00012	0.00012	0.00005	0.00024	0.00182	)
Mammography	-0.17721	0.01078	-0.03994	-0.00026	0.00586	0.99905	
	(0.00013	0.00024	0.00012	0.00015	0.0015	0.00049	)
Chemotherapy	-0.03634	0.00257	-0.01208	-0.00365	0.03412	0.55035	
	(0.00001	0.00005	0.00003	0.00004	0.00018	0.00462	)
Radiation	-0.07413	0.08913	0.0114	0.00744	0.00381	0.99903	
	(0.0002	0.00012	0.00007	0.0001	0.00101	0.00051	)

Table 3 describes the results of our preliminary work applying the multi-variate signal extraction methods to analyzing treatment patterns and outcomes for breast cancer. The methods offer advantages over our earlier IV statistical methods in two ways. First, the methods filter out patient level variation that is unsystematic, helping with the problem of bias due to differences in patient characteristics. Also, the methods permit an IV analysis (here, using hospital 'quality' as the IV) considering multiple treatments jointly, helping with the problem of bias due to correlated treatments. The early results do result in a treatment effect estimate that is of more reasonable magnitude than our earlier differential IV analysis, and definite treatment patterns emerge. The first factor could be labeled the "mastectomy+BCS+radiation" factor, while the second factor is the "mastectomy+radiation" factor. However the direction of the treatment effect is negative, although the magnitude of the mortality difference is extremely small. This suggests that not all of the selection bias is accounted for, and indeed analysis of correlations between the factors and our index measures of severity continue to show strong relationships. In our future work, we will continue to refine our measures of treatments and outcomes to better reflect current practice, and experiment with alternative specifications. For example, we could combine the differential distance IV method and the multi-variate signal extraction method, extracting signal among differential distance groups. Initial work has been promising and was ongoing at the end of the current project period.

C. Conclusions

C.1. Principal Findings

A principal cause of the limited evidence on trends and cost-effectiveness of cancer care for the

elderly is the absence of precise information on the utility of medical claims databases for understanding cancer epidemiology, treatments, cost, and outcomes. The uncertainty about the cost-effectiveness of alternative cancer screening and treatment practices in elderly populations underscores a critical need for more research on treatments, costs, and outcomes based on large, representative population groups. The project made substantial progress in (1) constructing a set of rules for identifying cancer cases in administrative data with much higher sensitivity and specificity estimates and more accurate time of diagnosis estimates than previous reported; and (2) demonstrating the feasibility on breast cancer of an important methodological step (instrumental variables and multi-variate signal extraction) necessary for attributed differences in outcomes to treatment differences.

While additional research is required to continue to develop new methods for accounting for problems of bias that confound the treatment effect analysis, the project did produce several definitive findings.

1) *Access to care.* The IV results showed a persistent relationship between differential distance and rates of diagnosis and health status conditional on diagnosis, including co-morbidities, stage at diagnosis, and subsequent outcome. Where you live in part determines your level of diagnosis, treatment, and mortality.

2) *Productivity.* The analysis of trends in incidence, treatment, and costs lead to findings that the productivity of breast cancer care has been neither increasing or decline over the past few decades. For breast cancer, changes in screening or case-finding as well as changes in treatment given diagnosis had important implications for productivity analysis. Ignoring changes in incidence, cohort analysis of outcomes and expenditures for breast cancer suggested significant improvements in productivity. However, from population perspective the productivity improvements were only modest. There is little evidence however for declining productivity, i.e., cost increases were matched or exceeded by outcome improvements as suggested by the simple trends.

C.2. Areas of Future Research

Additional work is needed in several areas identified in this research. Specifically,

1) The determinants of area differences in diagnoses and treatment. Clearly access as defined by travel distance to a major cancer provider had important implications for early state detection and subsequent treatment and outcomes. Additional research needs to identify the causes of limited access to diagnosis and treatment.

2) Screening cohorts. Our IV and productivity analysis demonstrated the importance of diagnosis in the analysis of treatment effects. Simply focusing on treatment conditional on diagnosis can lead to different results than when changes in case-finding are taken into account. Our cohorts are based in part on treatment, as the case finding method in part relies on treatments received. Accounting for differences in the probability of being diagnosed required creation of screening cohorts, but it is still difficult to separate out diagnosis from treatment conditional on diagnosis using medical claims

information from Medicare. Work is continuing in this area.

3) Cause-of-death specific analyses. Another approach to removing the impact of differences in patient co-morbidities is to evaluate the effect of treatments on cancer-specific causes of death. Work on imputing a cause of death to our cohorts is ongoing.

4) Cost-effectiveness. While the IV and multi-variate signal extraction methods hold promise for resulting in unbiased estimates of treatment effects, work continues on defining improved treatments and outcome measures, and refining the empirical methods to account for patient selection.

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Is Technological Change in Medicine Worth It?

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We are grateful to Hugh Roghmann for research assistance, and to the National Institutes on Aging, the Bureau of Labor Statistics, the Bureau of Economic Analysis, and Eli Lilly Corporation for research support.

It is widely accepted that technological change accounts for the bulk of medical care cost increases over time. But is technology therefore bad? That conclusion does not necessarily follow. Presumably, technological change brings benefits in addition to costs – increased longevity, higher quality of life, less time absent from work, and so on. These benefits need to be measured and compared to the costs of technology before welfare statements can be made. Technological change is bad only if the cost increases are greater than the benefits.

In aggregate, both the costs of medical care and health have improved over time. Given then-prevailing medical spending by age, the average newborn in 1950 could expect to spend $8,000 in present value on medical care over their lifetime. The comparable amount in 1990 is $45,000. Concurrent with this increase has been a substantial improvement in health. The same infant had a 7 year greater life expectancy in 1990 than in 1950. And disability rates were declining as well.[1]

But how much of the health improvement is a result of medical care? Is the medical component big enough to justify the cost? That question is the most central one in the economic evaluation of medical technology, and is the subject of this paper.

We report on a series of studies that examine whether medical technology changes are worth their cost. A key feature of these studies is that they measure costs and benefits of technological change at the disease-level, not the level of medical spending as a whole. Health improvements in aggregate are difficult to parcel out to different factors; health improvements at the disease level are also difficult, but more manageable. While studying medical technology at the disease level gives up the immediate possibility of making aggregate statements about the

medical system as a whole, it allows one to say with some degree of confidence what medical care is worth in particular settings. It also illustrates the multiple mechanisms through which technology affects costs and outcomes. Our analysis considers for five conditions: heart attacks; low birth weight babies; depression; cataracts; and breast cancer.

The results we present highlight the good and bad of technological change. For most of the conditions that we consider, technological change is on net valuable. Treatment changes for heart attacks, low birth weight infants, depression, and cataracts all clearly have high benefits. The technology used in treating these conditions is costly, but the benefits in longer, healthier life are even greater. For breast cancer, technological change has brought benefits roughly equal to cost. There may be small positive or negative effects of technological change, but these are not great.

The key to understanding these results is to recognize the different ways in which technology affects the medical system. New technologies often substitute for older technologies. For example, new medications for treatment of depression replace older medications and psychotherapy. The unit cost of new technologies may be higher or lower than the cost of the older technologies they replace. Health outcomes are generally better, however, and since health is valued so highly, this substitution of newer for older treatments is typically welfare-improving.

In addition, new technologies frequently lead to more people being treated for the disease, which we term the 'treatment expansion effect'. When treatment is effective, getting more people into treatment is beneficial. Depression, for example, was notoriously underdiagnosed and undertreated prior to the development of selective serotonin reuptake inhibitors in the late 1980s. Increased treatment rates were thus worth the cost. In other cases, treatment is expensive

and not so effective, so expanding therapy to more people increases costs without commensurate gains. Breast cancer diagnosis and treatment rates increased over the 1980s and 1990, but the benefits of expanded care just barely kept pace with the additional costs. The treatment expansion effect is thus a significant part of the benefits and the failures of technological innovation.

Our results have a number of implications for health policy. The finding that technological innovation is welfare improving in many cases means that medical spending should optimally increase over time, not be held constant as some have suggested. Further, our results imply that the quality-adjusted price of medical care is actually falling over time, in contrast to standard statistics showing rising prices for medical services. Finally, our results provide a valuable methodology for gauging the impact of health system change such as the rise of managed care on consumer welfare.

I. The Costs and Benefits of Medical Innovation

Measuring the value of medical innovation requires a conceptual understanding of the costs and benefits associated with it. Table 1 presents our framework. The direct treatment costs are those associated with the disease under study. Such costs may be incurred in the immediate aftermath of an acute event or several years later.

The most important benefit of medical innovation is the value of better health – longer life and/or higher quality of life. There may be other effects of technology on production possibilities. A new pharmaceutical that lets people recover from an illness and return to work more rapidly, for example, has benefits equal to the additional output it lets people produce (in

addition to the health benefit). Finally, the health and productivity benefits must be offset by the medical and non-medical costs of keeping a person alive if the technology improves longevity or otherwise adds to resource needs.[2] **MM: I put this on benefits side because we normally subtract it from value and compare to direct treatment costs in empirical work. Conceptually, it belongs on the cost side.**

The net benefit of medical technology change is the dollar value of the health and productivity benefits less the dollar value of direct treatment and other costs. A positive net benefit implies that the technological change is worth it in total. A negative value implies that it is not.

Valuing health improvements is obviously difficult. We follow the consensus of the literature[3] and measure health using the quality-adjusted life year (QALY) approach. In practice, many (but not all) of the conditions we consider have high fatality rates, so we often measure just longevity. Again following the literature,[4] we assume the value a year of life in the absence of disease is $100,000. We explore the sensitivity of our results to variations in this parameter. Perhaps surprisingly, the results we present are generally true for a vast range of values of life. Finally, we discount costs and benefits in the future to current dollars using a 3 percent discount rate. The qualitative results we present are not very sensitive to this discount rate.

The Disease Approach. The central empirical issue in implementing this framework is determining the importance of medical technology changes for better health. A variety of factors may influence health over time, including medical care, public health measures, environmental changes, individual behavioral responses, changes in socioeconomic circumstances, new disease

patterns, and so on. Separating out the role of medical care from these other factors is a daunting task.

We do not attempt such a decomposition in aggregate. Rather, we focus on the disease level. Using observational data or clinical trial evidence, we can often tell at the disease level how important medical technology is to better health.[5] Even when the analysis at the disease level is not exact, the range of uncertainty is generally better understood, so more refined sensitivity analysis can be conducted.

The cost of analyzing technological change at the disease level is that one needs to study many diseases to make statements about the medical system as a whole. While we summarize results for many conditions, we do not yet have a sufficiently broad understanding of the medical system as a whole. But many conclusions can be drawn, and the mechanisms through which technological change affects welfare can be drawn out. Thus, the advantages of this approach far outweigh the disadvantages.[6]

II. A First Example: Technology for Heart Attacks

To demonstrate the nature of the analysis, we consider one example in detail, the treatment of heart attacks. A heart attack is an acute medical event characterized by the occlusion of the arteries that supply blood to the heart. Without adequate oxygen, part of the heart muscle dies. The task of medical treatment is to restore blood flow as rapidly as possible and to prevent further recurrence of a heart attack or coronary damage on an ongoing basis.

Heart attacks are natural to examine because they are common, they cost a lot of money to treat, technology for treating heart attacks has changed rapidly over time, and outcomes are

readily measured. In addition, virtually all heart attacks are know about, so selection into treatment is not an important issue. Substantial work has been done on the costs and benefits of technological change in heart attack care, including some by us and coauthors Joseph Newhouse and Dahlia Remler.[7] We extend those results here.

Treatment Options. The most common therapy for treating heart attacks is thrombolysis, drugs that dissolve the clot in the coronary artery and thus restore blood flow to the heart. Early thrombolytic drugs (**is heparin a thrombolytic?**) were developed in the 1950s and 1960s (**???**). The 1970s and 1980s saw the development of newer, slightly more effective medications.

An alternative to thrombolysis is surgical intervention to restore blood flow. Such surgery takes two forms. Bypass surgery, developed in the late 1960s, involves grafting an artery or vein around the occluded coronary artery and thus restoring blood flow. Angioplasty, developed in the late 1970s, involves use of a balloon catheter to break up the clot. Since the mid-1990s, angioplasty has increasingly been used with one or more stents, small devices that hold open the coronary artery. Both bypass surgery and angioplasty will be preceded by cardiac cathereterization, a diagnostic procedure to measure the location and extent of arterial blockage. Other therapeutic technologies include drugs to reduce the workload of the heart, regulate the heart's rhythm, and prevent the formation of new clots.

Many of these surgical technologies have improved over time. Bypass surgery mortality has been falling, for example, as physicians and nursing teams become more skilled in the use of the technology. Thus, technological change is both process innovation in existing therapies as well as the development of entirely new therapies.

Data. To measure the costs and benefits of these treatment changes, we use data from Medicare claims records. Our samples consist of every Medicare beneficiary in the fee-for-service Medicare program that had a heart attack between 1984 and 1998. We do not have data from managed care enrollees. For most of this time period, such enrollment was relatively small. But gathering data on managed care enrollees will be increasingly important as managed care enrollment among the elderly population increases.

Mark to describe data more – are md claims in there too? All of our expenditure data are expressed in real (**1993???**) terms, relative to prices in the economy as a whole.

The Medicare data have been linked with Social Security death records through **1999?**, so we can measure survival for heart attack patients. Mortality is a frequent consequence of heart attacks, so survival is a good measure of health.

Treatment Costs. Table 2 shows information on the costs of treating heart attacks over time. In 1984, $3 billion was spent on care for heart attack patients. By 1998, the total was near $5 billion, for a 3.4 percent growth in real terms. This increase is not a result of more people having heart attacks. As the next row shows, the number of heart attacks declined by almost 1 percent a year, despite a significant increase in the fee-for-service Medicare population over this time period. The reduction in heart attacks is likely a result of better risk factor management such as reduced smoking and better blood pressure and cholesterol control. With fewer heart attack cases but more total spending, the implication is that spending per heart attack increased. This is shown n the third row. The increase in spending on heart attacks was substantial, a rise of nearly $10,000 per case in real terms, or 4 percent per year.

The last two rows help to understand why spending increased. We decompose per case spending growth into a share attributable to increased prices and a share attributable to changes in treatment shares. To measure prices and treatment rates, we group the patients into five treatment options corresponding to Medicare reimbursement methodology: medical (non-surgical) management of the heart attack; cardiac catheterization with no revascularization procedure; angioplasty without use of stents; angioplasty with use of stents; and bypass surgery. In each case, we calculate average Medicare reimbursement and the share of patients receiving each treatment over time.

As the bottom rows of the table show, changes in treatment rates are the more important factor in explaining spending increases. Nearly half of cost increases result from people getting more intensive technologies over time. Price changes are a smaller share. Indeed, even this estimate of the technological component is likely to be too low since some price increases are due to technological change within the treatment categories, and should properly be called quantity changes. In total, therefore, technological change accounts for half or more of cost growth for heart attacks, a finding consistent with previous literature about the sources of cost growth for the medical sector as a whole.[8]

Figure 1 shows the nature of this technological change. In 1984, only 10 percent of heart attack patients received some surgical intervention; nearly 90 percent of patients were managed medically. By 1998, over half of heart attack patients received some surgical therapy. Nearly a quarter received balloon angioplasty, which had barely been invented by 1984.

Comparing Costs and Benefits. The increasing cost of heart attack treatment must be

weighed against the benefits of this innovation. Both length and quality of life may be affected by treatment changes. Because length of life changes are so large and good data on quality of life are not readily available, we analyze changes in length of life only. Other work we have done suggests that accounting for changes in quality of life would strengthen the conclusions here.[9]

We measure survival after a heart attack in several steps. In those years for which sufficient long-term data are available, we measure survival directly for up to 5 years after the heart attack. We adjust the survival data for changes in the age and sex mix of the heart attack population over time. In years where 5 years of follow-up data are not available (for example, heart attacks occurring in 1998), we extrapolate from previous years, using a conservative approach that understates mortality improvements.[10] We assume that after five years, survival is the same for all cohorts of patients and is equal to life expectancy for the population as a whole, increased by the differential mortality for heart attack patients as compared to the elderly population as a whole. This too is conservative as mortality rates are declining within the first five years after the heart attack and there is no reason to expect that trend to stop after five years. Thus, our estimates are designed to understate the value of technological change.

Table 3 shows the analysis of the costs and benefits of treatment changes. The first two columns report the increase in treatment costs from Table 2. The next two columns present our estimates of life expectancy after a heart attack. Life expectancy for the average person with a heart attack was just under 5 years in 1984, but had increased to 6 years by 1998.

As noted above, we assume the value of a year of life is $100,000. Since most heart attack survivors do not work, the value of increased production resulting from extended life is zero. Annual consumption for the elderly averages about $25,000, which we take to be the basic

medical and non-medical cost of living. Thus, the benefit to society of an additional year of life for heart attack patients is $75,000 ($100,000 - $25,000). As table 3 shows, with this net valuation the present value of the longevity benefits is about $70,000.

Comparing the near $70,000 of benefit with the $10,000 of cost increase makes it clear that technological change in heart attack care is worth the cost. Technology increases spending, but it is worth it.

The net benefit of technology changes is so large that it dwarfs all of the uncertainties in the analysis. For example, not all of the improvement in survival results from changes in intensive treatments. Detailed analysis of heart attack mortality changes suggests that 80 to 90 percent of the survival improvement is a result of changes in technology, with the remainder coming from changes in risk factors such as smoking.[11] Still, even if one took away 20 percent of the benefits, technological change would still be overwhelmingly worth it. Similarly, the value of a year of life need only be one-third of what we assume to make the technological change worth it. And we have omitted any changes in quality of life, which likely adds to the benefit of technological change.

One question we are not able to address with these data is which particular technologies were most responsible for the improvement in health. Because the range of technologies is so vast, and the interaction between technologies is so complex, such an analysis is not possible with claims data alone. Attempts to examine this issue using data from clinical trials have generally concluded that most of these technologies have contributed to improved survival.[12] But one point about the various technologies is important. Most of the technological change observed in heart attack care is not the development of entirely new therapies. Only one such

therapy was developed in this time period. Rather, technological change is predominantly the extension of existing technologies to more patients.

III. The Range of Other Conditions

If most medical innovations were like heart attacks, it would be clear that medical technology changes were worth the cost. But there is no guarantee this is the case. Ultimately, technologies must be evaluated on a case-by-case basis. Several recent studies have examined the costs and benefits of technological change for a range of different conditions. Table 4 summarizes these studies. The first row is the heart attack example presented in the previous section. We discuss the other conditions in turn.

Low Birth Weight Infants. Cutler and Ellen Meara[13] examine the costs and benefits of technological change in the treatment of low birth weight infants. Data on neonatal mortality by birth weight are available from 1950 through the 1990s.

In 1950, very little could be done for low birth weight infants. Mortality for infants born under 2500 g was 18 percent, and mortality for even lighter infants born under 1500 g was 70 percent. With little to do, costs of caring for these infants was low. By 1990, there was a substantial armamentarium of medical technologies available to treat low birth weight infants, ranging from special ventilators to artificial surfactant to speed the development of the lungs. Such technology is expensive. The lifetime costs of caring for a low birth weight infant, including costs during the birth period, costs of treating medical complications resulting from premature birth (such as cerebral palsy), and related non-medical costs such as special education

and disability payments, were about $40,000 in present value.[14]

Survival improved as well. In 1990, mortality for low birth weight infants was only one-third the level in 1950. The overall increase in life expectancy is about 12 years per low birth weight baby. Further, quality of life has, if anything, improved. At the margin of viability, there are high rates of medical and developmental problems. But as survival has improved at lower birth weights, infants above those birth weights are increasingly healthy. Thus, the share of all low birth weight babies with severe complications is falling. For convenience, we focus on the longevity gains alone.

Babies who survive birth will both produce (absent the disability issue noted above) and consume resources. Over a person's lifetime, these two factors roughly cancel – the average person neither inherits much nor leaves a substantial bequest. Thus, the benefits to increased survival are just the health benefits from increased longevity, or $100,000 per year of additional life.

With this valuation, the present value of the additional longevity is about $240,000 per low birth weight infant.[15] Compared to the $40,000 of increased cost, the net benefit is $200,000. This net benefit is so large that it dwarfs all of the uncertainties inherent in the data. The value of a year of life, for example, need be only one-sixth its estimated value for the technology to be worth it. The low birth weight example thus reaches a conclusion similar to that for heart attacks: technological change increases spending, but the benefits are even greater.

Depression. Richard Frank, Ernst Berndt, Susan Busch, Sharon-Lise Normand, and Anupa Bir[16] analyze changes in the treatment of depression in the 1990s. They use claims data

on several thousand episodes of depression over the 1991-96 time period. This time period is shorter than that used in the analysis of heart attacks or neonatal mortality, but it spans a particularly important period in the treatment of depression, when new medications such as SSRIs (including Prozac and related medications) were introduced.

Mortality is not a common outcome for depressed people, and quality of life is not available in claims data. Thus, Frank et al. use an indirect method of analyzing the costs and benefits of technological change. They combine data on changes in treatment patterns and costs in the claims data with clinical trial evidence on the efficacy of treatments in reducing depressive symptoms.

Large changes in medical treatments occurred over this time period. In the mid-1980s, treatment with either psychotherapy or tricyclic antidepressants was the norm. SSRIs displaced each of these other therapies. By 1991, several years into the SSRI revolution, 30 percent of patients were treated with an SSRI. In 1996, the share was nearly half. The increased use of SSRIs was not because they reduce depressive symptoms more effectively than older therapies. Clinical trial evidence suggests that psychotherapy, tricyclic antidepressants, and SSRIs have roughly equivalent efficacy, with the two medications being somewhat better in some cases and generally similar to each other in efficacy. But SSRIs have many fewer side effects than tricyclic medications, are easier for physicians to dose, and cost patients less than psychotherapy. Thus, they became the dominant form of therapy.

Pharmaceuticals are less expensive overall than psychotherapy for a full course of therapy, and about the same cost when dropouts from both therapies are included. Thus, the shift from psychotherapy to prescription medications was accomplished at virtually no net cost. But

dropout rates are higher for psychotherapy or tricyclic antidepressants than for SSRIs. The ease of taking medications compared to visiting a psychotherapist, the lower out-of-pocket costs that SSRIs have over psychotherapy, and the reduced side effect profile of SSRIs in comparison to tricyclic medications led more people to stay on SSRIs through guideline levels. As a result, treatment effectiveness increased. Frank et al. calculate that this increase in treatment efficacy reduced spending per incremental remission probability by about 20 percent over the time period.

But technology did even more. Numerous studies prior to the 1990s estimated that about half of people with depression were not correctly diagnosed by the physician, and many of those diagnosed did not receive clinically efficacious treatment.[17] The SSRIs were heavily promoted by pharmaceutical companies, and physicians and patients were reminded of this poor history. SSRIs also medicalized the diagnosis of depression, reducing some of the stigma associated with seeking mental health treatment.

As a result, diagnosis and treatment for depression soared over the 1990s. This increase in the share of people treated for depression has both costs and benefits. Treating an episode of depression costs up to $1,000, depending on the type of therapy followed. The health benefits of treatment are reduced time spent depressed. Data suggest that effective treatment can reduce time spent depressed by perhaps 12 weeks. The quality of life improvement from reducing depressive symptoms has been estimated by several studies, with estimates ranging from -0.1 to as much as -0.6, on a scale where -1 is moving from perfect health to death.[18] Using an intermediate value of -0.4, and assuming a year of life is worth $100,000, the reduction in time spent depressed is a benefit of about $6,000. This is six times greater than the cost of treatment. In addition, there are gains from people being able to work and produce more, which are not in

this calculation. Thus, increasing rates of treatment brought about by newer medications is worth the cost.[19]

Cataracts. Irving Shapiro, Matthew Shapiro, and David Wilcox[20] consider technological change in the treatment of cataracts from the late 1960s through the late 1990s. In the late 1960s, a cataract operation was a very intensive procedure. It involved three nights in a hospital (down from a week a few decades earlier), and substantial operating room and physician time. Complications were frequent, including glaucoma and infection. By the late 1990s, in contrast, cataract operations were routinely performed on an outpatient basis in under half an hour, with many fewer complications. Post-operative visual quality has also improved.

The reduction in inputs needed for the operation has offset the increase in cost of each input. Even though hospital and surgeon fees have increased, for example, so many fewer resources are needed to perform the operation that total operative costs for a cataract operation are essentially unchanged in real terms. With no increase in spending over three decades and a large increase in visual quality and reduction in complication rates, the treatment of cataracts is a clear case of technological change with positive net benefits.

There is another effect of technological change in cataracts, similar to that in depression. Technological change has increased the number of people who get a cataract operation. People are operated on at much less severe measures of visual acuity now than in the past. Many more people ultimately get cataract operations now. Deciding whether this change in treatment rates is valuable or not requires a comparison of the benefits of better vision with the cost of a cataract operation. A rough calculation illustrates the order of magnitude. Medicare reimbursement for a

cataract operation is about $1,500. The benefits of the operation are several years of improved vision. Estimates in the literature suggest a quality of life decrement from vision impairment associated with cataracts of about -0.2. For a person with five years of remaining life expectancy, this amounts to one year of improved quality-adjusted life. Valuing this at $100,000 (since the people are mostly elderly and there are few productivity gains) gives a present value of about $95,000, which is substantially greater than the cost. One would need data on the age and life expectancy of cataract operation recipients to do this calculation precisely, but the treatment-inducement effect almost certainly is beneficial.

Breast Cancer. We have recently analyzed the costs and benefits of treatment changes for breast cancer over the period from 1985 to 1996.[21] Over time, several new innovations in therapeutic treatment of breast cancer have been made. **MM to describe more**. These technological changes have added about $20,000 to per case costs over the 11 year period.

In addition, detection technology has advanced. Screening for breast cancer increased markedly over this time period and more sensitive screens allowed detection of smaller masses. As a result, overall cancer diagnosis and treatment rates rose. Between 1985 and 1991, for example, breast cancer incidence rates increased 10 percent. This was offset partially in subsequent years by reduced rates of metastatic disease from cancers caught earlier, but incidence rates were still higher even a decade later.

To measure the benefits of these diagnostic and therapeutic changes, we calculate survival for women as a whole as a result of reduced breast cancer mortality. Looking only at mortality for women with breast cancer gives a biased estimate of the impact of technological

change, as many of the new women treated will have much less severe cases of disease than women detected in previous years, and thus will naturally live longer.[22] **MM: I think the only way case-based survival can increase and population survival be flat is because of selection. Is this true?** We express these population-based survival improvements on a per case basis to compare with per case treatment costs (or alternatively, the per case costs could be converted to a population basis).

Survival after breast cancer increased by 4 months over this time period. The value of a year of life for a woman with breast cancer is the $100,000 health benefits less the $25,000 of basic medical and non-medical costs. Because the women we analyze are elderly and most are out of the labor force, we assume no increased production. With a $75,000 net benefit of a year of life, the increase in survival is worth about $20,000. The value of increased survival is thus roughly equal to the cost increases for treating breast cancer. On net, technological change was neither beneficial nor harmful.

There are uncertainties in this calculation that could make technological change valuable or not. For example, we have not accounted for quality of life, which is believed by many to have improved over this time period. On the other hand, we have counted only treatment costs and have omitted the substantial increase in screening costs. These uncertainties are in addition to the usual uncertainty about the value of a year of life. On net, the costs and benefits are so close and the uncertainties sufficiently high that we conclude that technological change was probably neutral, with no large change either way.

Understanding why technological change in breast cancer was not as valuable as technological change for other conditions is difficult. **MM to write more here.**

Summary. The case studies show two roles through which technological change affects the medical system. First, new technologies substitute for older technologies in the treatment of recognized cases of disease. Examples of this substitution effect include angioplasty replacing thrombolysis or bypass surgery in heart attack patients, and SSRIs replacing psychotherapy and tricyclic antidepressants for patients with depression. Treatment costs may increase or decrease when new technologies substitute for older ones; our examples show both scenarios. And the technology may or may not be beneficial.

Second, technological change expands the share of patients diagnosed and treated. Many patients with depression were not diagnosed as such or did not seek treatment prior to SSRIs. Many people with cataract-induced poor vision were not considered candidates for therapy prior to easy surgical techniques. Many more cases of breast cancer were discovered and treated with more regular screening. This treatment-inducement effect is almost always cost increasing, since prior to the diagnosis there was no therapy provided. It may or may not be worth it to extend care to more patients, depending on how valuable the underlying treatment is. The failures of the medical care system, and some of its great successes, are in this treatment-inducement effect. But it has received remarkably little study by researchers.

IV. Policy Implications

These results raise a host of issues for health policy. We note them briefly in this section.

Is medical technology as a whole worth it? An important question is what conclusion one should draw about technological change as a whole. While we have considered a range of

conditions, we have not considered enough to draw very firm conclusions. Most importantly, the analysis to date has focused on acute conditions, leaving aside technological change in the care of chronic disease such as diabetes, asthma, and congestive heart failure. Extending the analysis in this direction is an important avenue for research.

Of course, one can never analyze all medical conditions. But by choosing conditions carefully, we expect that conclusions can be drawn about perhaps half of medical costs without significant difficulty. This scale of analysis would permit inferences about the value of medical technology as a whole.

In considering this aggregate question, though, we provide a calculation that illuminates the issue.[23] Consider the facts given in the introduction to this paper: Between 1950 and 1990, the present value of per person medical spending increased by $35,000 and life expectancy increased by 7 years. Valuing these years at $100,000 per year, the present value of the increase in longevity is about $130,000. Thus, the increase medical spending as a whole is worth it if medical spending explains more than a quarter ($35,000 / $130,000 = 27%) of increases in longevity. Note that this calculation ignores changes in quality of life, which substantial evidence shows has improved over time. Thus, the required share for medical care to be welfare improving may be even lower.

We let readers judge whether or not they believe a quarter of longer life results from medical technology changes. In the cases we have analyzed where mortality has been declining (heart attacks and low birth weight births), the medical component of mortality reductions is well over one-quarter. Thus, our strong suspicion is that technological change as a whole is worth the cost. **Want to be stronger here?**

Price Indices for Medical Care. Official data indicate that medical prices are increasing more rapidly than prices in the rest of the economy. For example, between 1960 and 1999, the medical care CPI increased by 1.8 percentage points annually above the growth rate of the all-items CPI.

There are two problems with such indices. First, they include as price changes many factors that are more accurately counted as quantity increases resulting from medical innovation. For example, a day in a hospital was traditionally included in the CPI, with a very rapid price increase, but this price increase was almost certainly a result of increased technological sophistication of a day in the hospital.

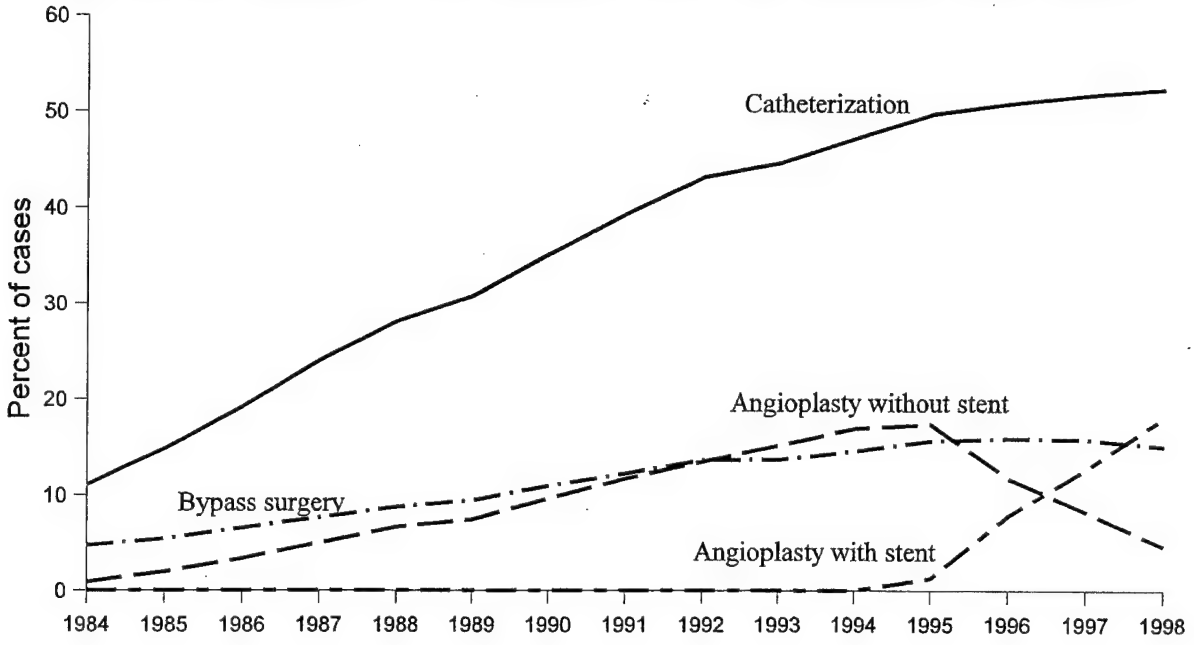
More fundamentally, official price indices have only a poor adjustment for quality change. If price increases over time are matched by quality improvements, the quality-adjusted price of medical care will not increase. Our results imply that quality change has been even greater than price increases for many conditions. Thus, the quality-adjusted price index for these conditions should be declining. An equivalent statement is that productivity in treating these conditions has been greater than that of the typical industry. Government statistical agencies are beginning to incorporate quality adjustment into official indices[24] – as demonstrated here, this is a difficult task – and we expect that continued changes in this direction will substantially reduce the perceived inflationary-component of medical care cost increases.

Managed care. Our analysis has focused on technological changes in medical practice over time, but it is equally applicable to technological changes in the delivery system, such as the growth of managed care. Managed care clearly lowers medical spending. This cost saving must

be compared to any effect of managed care on the quality of medical services provided, either improvements in quality as advocates claim, or reductions in quality as detractors fear. The net benefit of managed care is the cost savings less the value of reduced health (or plus the value of health improvements).

Estimating the health impacts of managed care can be done with the same sort of data that we have analyzed in this paper, expanded to include people in different insurance plans. Thus, we believe there are no insurmountable barriers to estimating whether delivery system change has been on net valuable or harmful.

Figure 1: Changes in The Treatment of Heart Attacks, 1984-1998



Note: The sample is all elderly patients with a heart attack in those years.

Table 1: Summary of the Costs and Benefits of Medical Technology Change

Direct Treatment Costs	Benefits
Current and future medical costs for treating condition	Value of longer and/or higher quality life
	Additional production net of increased medical and non-medical costs of living.

Table 2: Accounting for the Increased Cost of Heart Attack Treatments

	1984	1998	Annual change
Total spending	$3.0 bn	$4.8 bn	3.4%
Number of cases	245,687	221,133	-0.8%
Average spending per case	$12,083	$21,714	4.2%
Share of spending increase due to:			
Treatment changes	45%		
Price change	33%		

Note: The last two rows do not add to 100 percent because of the covariance between price changes and treatment changes.

Table 3: Costs and Benefits of Treatment Change for Heart Attack Patients

	Treatment Costs		Benefits	
Year	Amount	Change	Life Expectancy	Value
1984	$12,083	—	4 yr 11 mo	—
1998	21,714	$9,631	6 yr 0 mo	$70,252

Note: Value of a year of life is $100,000. Medical and non-medical cost of living are $25,000 and are subtracted from the benefits of increased longevity.

Table 4: Research on the Value of Medical Technology Changes

			Outcome		
Condition	Years	Change in Treatment Costs	Change	Value	Net Benefit
Heart attack	1984-98	$10,000	1 year increase in life expectancy	$100,000	$90,000
Low birth weight infants	1950-90	$40,000	12 year increase in life expectancy	$240,000	$200,000
Depression	1991-96	$0	Higher remission probability at some cost for those already treated.		
		>0	More people treated, with benefits exceeding costs.		
Cataracts	1969-98	$0	Substantial improvements in quality at no cost increase for those already treated.		
		>0	More people treated, with benefits exceeding costs.		
Breast cancer	1985-96	$20,000	4 month increase in life expectancy	$20,000	$0

Note: Individual studies are discussed in the text.

Footnotes

1. Kenneth G. Manton, Larry Corder, and Eric Stallard, (1997), "Chronic Disability Trends in Elderly United States Populations: 1982-1994", *Proceedings of the National Academy of Sciences*, 94: 2593-2598.

2. There is substantial debate about whether such costs ought to be included in the analysis or not. The United States Department of Health and Human Services, Panel on Cost-Effectiveness in Health and Medicine, *Cost-Effectiveness in Health and Medicine*, Washington, D.C., 1997, and David Meltzer, "Accounting for future costs in medical cost-effectiveness analysis," *Journal Of Health Economics* (16)1, 1997, 33-64 present opposing views. Conceptually, such costs ought to be included, but so too should the gains from extending longevity. To see why, consider the case of a medical technology that, at low monetary cost, would extend the life of a person just about to die by one additional year. The technology will be worth it if the value to society of the person living a year is greater than the cost to society of having the person alive. Omitting either the costs or benefits from this equation biases the answer.

3. Panel on Cost-Effectiveness in Health and Medicine, *Cost-Effectiveness in Health and Medicine*.

4. W. Kip Viscusi, "The Value of Risks to Life and Health", *Journal of Economic Literature*, 1993, 1912-1946; George Tolley, Donald Kenkel, and Robert Fabian, eds., *Valuing Health for Policy: An Economic Approach*, Chicago: The University of Chicago Press, 1994; Kevin Murphy and Robert Topel, "The Economic Value of Medical Research", mimeo, 1999.

5. This is also the approach followed by John P. Bunker, Howard S. Frazier, and Frederick Mosteller, "Improving Health: Measuring Effects of Medical Care", *The Milbank Quarterly*, 72 (2), 1994, 225-258.

6. This approach is conceptually similar to the understanding of investment at the aggregate level, which involves the analysis of about 800 separate types of investment. See Jack Triplett, "What's Different About Health? Human Repair and Car Repair in National Accounts and National Health Accounts", forthcoming in David Cutler and Ernst Berndt, eds., *Medical Care Output and Productivity*, Chicago: University of Chicago Press, 2001.

7. David M. Cutler, Mark McClellan, Joseph P. Newhouse, and Dahlia Remler, "Are Medical Prices Falling?" *Quarterly Journal of Economics*, November 1998, 991-1024; David M. Cutler, Mark McClellan, Joseph P. Newhouse, and Dahlia Remler, "Pricing Heart Attack Treatments", forthcoming in David Cutler and Ernst Berndt, eds., *Medical Care Productivity and Output*, Chicago: University of Chicago Press, 2001.

8. Joseph P. Newhouse, "Medical Care Costs: How Much Welfare Loss?" *Journal of Economic Perspectives*, 6(3), Summer 1992, 3-21; David M. Cutler, "Technology, Health Costs,

and the NIH", paper presented at the National Institutes of Health Economic Roundtable on Biomedical Research, 1995; Edgar A. Peden and Mark S. Freeland, "A Historical Analysis of Medical Spending Growth, 1960-1993, *Health Affairs*, 14(2), Summer 1995, 235-247.

9. Cutler, McClellan, Newhouse, and Remler, "Pricing Heart Attack Treatments".

10. In particular, we assume that hazard rates for dying in years after a heart attack are equal to the value in the most recent year known. For example, the mortality hazard rate 2 years after a heart attack for the 1998 cohort is assumed to equal the mortality hazard rate 2 years after a heart attack for the 1997 cohort. This is conservative because hazard rates are generally declining over time, and we are assuming no change.

11. Paul A. Heidenreich, and Mark McClellan, "Trends in Treatment and Outcomes for Acute Myocardial Infarction: 1975-1995." *American Journal of Medicine.* 110(3): February 15, 2001, 165-174.

12. Heidenreich and McClellan, "Trends in Treatment and Outcomes for Acute Myocardial Infarction: 1975-1995."

13. David M. Cutler and Ellen Meara, "The Technology of Birth: Is It Worth It?" in Alan Garber, ed., *Frontiers in Health Policy Research, Volume 3*, Cambridge, MA: MIT Press, 2000.

14. Average birth costs are about $20,000 per low birth weight baby. The remainder are Medicaid and disability spending for disabled children and special education costs for severely disabled children during school years. The probability that a child has any disability in 1990 is about two-thirds for the very lightest infants (<1000 g) and about one-quarter for the remaining low-birth weight infants. About half of children with disability are severely disabled.

15. The undiscounted value is $1.2 million. The present value is lower because a baby who survives will live about 70 years on average, and many of these years are far in the future.

16. Ernst R. Berndt, Anupa Bir, Susah H. Busch, Richard G. Frank, and Sharon-Lise T. Normand, "The Medical Treatment of Depression, 1991-1996: Productive Inefficiency, Expected Outcome Variations, and Price Indexes", NBER Working Paper No. 7816, July 2000; Richard G. Frank, Thomas G. McGuire, Sharon-Lise T. Normand, and Howard H. Goldman, "The Value of Mental Health Care at the System Level: The Case of Treating Depression", *Health Affairs*, 18(3), September/October 1999, 71-88; Ernst R. Berndt, Susan H. Busch, and Richard G. Frank, "Price Indexes for Acute Phase Treatment of Depression", forthcoming in David Cutler and Ernst Berndt, eds., *Medical Care Output and Productivity*, Chicago: University of Chicago Press, 2001.

17. See, for example, Robert M. Hirschfeld, Martin B. Keller, Susan Panico, et al., "The National Depressive and Manic-Depressive Association Consensus Statement on the Undertreatment of Depression", *Journal of the American Medical Association*, 277(4), January 22/29, 1997, 333-340.

18. David L. Sackett and George W. Torrence, "The Utility of Different Health States as Perceived by the General Public", *Journal of Chronic Diseases*, 31(11), 1978, 697-704; Dennis G. Frybeck, Erik J. Dasbach, Ronald Klein, Barbara E. K. Klein, Norma Dorn, Kathy Peterson, and Patricia A. Martin, "The Beaver Dam Health Outcomes Study: Initial Catalog of Health-State Quality Factors", *Medical Decision Making*, 13(2), April-June 1993, 89-102; Susan F. Anton and Dennis A. Revicki, "The Use of Decision Analysis in the Pharmacoeconomic Evaluation of an Antidepressant: A Cost-Effectiveness Study of Nefazodone,", *Psychopharmacology Bulletin*, 31(2), 1995, 249-258; Christopher J.L. Murray and Alan D. Lopez, eds., *The Global burden of disease : a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020*, Cambridge, MA: Harvard University Press, 1996.

19. In another metric, Frank et al. estimate that incremental spending per QALY is about $15,000, which is well below the value of a year of quality-adjusted life.

20. Irving Shapiro, Matthew D. Shapiro, and David W. Wilcox, "Measuring the Value of Cataract Surgery", in David Cutler and Ernst Berndt, eds., *Medical Care Output and Productivity*, Chicago: University of Chicago Press, 2001.

21. David M. Cutler and Mark McClellan, "The Productivity of Cancer Care", mimeo, 2001.

22. The data contain information on stage of detection, but not at a fine enough level to control for all the selection effects.

23. For discussion, see David M. Cutler and Elizabeth Richardson, "Your Money and Your Life: The Value of Health and What Affects It", in Alan Garber, ed., *Frontiers in Health Policy Research, Volume 2*, 1999, 99-132.

24. Ernst Berndt, David M. Cutler, Richard G. Frank, Zvi Griliches, Joseph P. Newhouse, and Jack E. Triplett, "Medical Care Prices and Output", in Anthony Culyer and Joseph P. Newhouse, eds., *Handbook of Health Economics, Volume IA*, Amsterdam: Elsevier, 2000, 119-180.